THOMPSON

Design of a
Highway Bridge

Civil Engineering
B. S.

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DESIGN OF A HIGHWAY BRIDGE

BY

McDONALD THOMPSON

THESIS FOR DEGREE OF BACHELOR OF SCIENCE
IN CIVIL ENGINEERING

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

McDonald Thompson

ENTITLED Design of a Highway Bridge

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Civil Engineering

Ira O. Baker,

HEAD OF DEPARTMENT OF Civil Engineering

Design of a Highway Bridge.

It is proposed to design a camel-back highway bridge which might replace a Pratt truss near the writer's home. The length of span center to center of end pins is 180 feet. This length is one at which no certain style of bridge can at present be said to be superior to all others. For longer spans, there is no doubt of the economy of the camel-back and Petit styles, while for shorter spans the Pratt truss is preferable. The dividing line seems to lie about 180 feet, which makes the design all the more interesting.

The data for the design is as follows:

Length of span 180 feet;
Height at portal 20 feet;
Height at center 29 feet;
Width of roadway 16 feet;
Capacity of floor system 100 lbs. per sq. ft.
Capacity of truss 50 lbs. per sq. ft.
Length of panel 20 feet.
Number of panels 9.

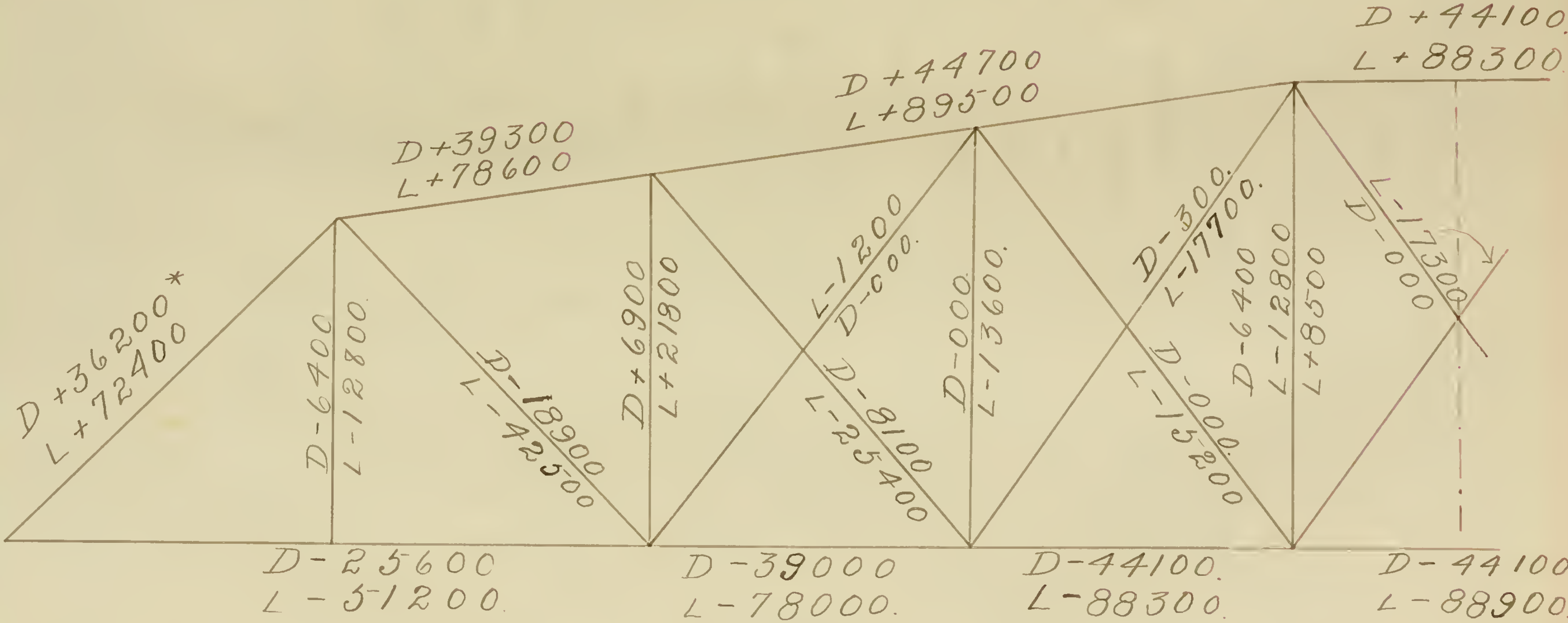
The design is to be made according to Coopers 1901 Specifications for Steel Highway Bridges.

Dead Load. After a preliminary investigation the dead load was taken at 640 pounds per lineal foot, or for panel concentration = $\frac{640 \times 20}{2} = 6400$ pounds per panel, all of which is considered as concentrated at the lower panel points.

Live Load. The live or moving load used is 80 pounds per square foot or $\frac{80 \times 16 \times 20}{2} = 1280$ pounds per panel.

Stresses. The dead and live load stresses were computed from panel concentrations by graphical resolution and checked by algebraic moments. All stresses are shown on the next page, each stress being placed in its proper place on the diagram.

Live and Dead Load Stresses



* + = compression.
  − = tension.

Design of Sections. Top chord; $U_1 - U_2$

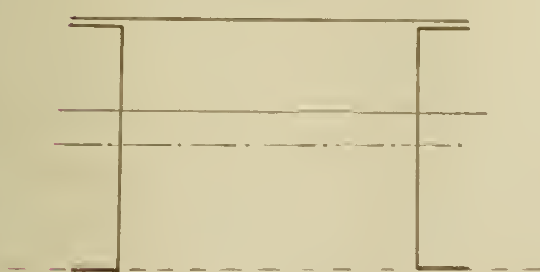
Dead load 39300 lbs.

Live load 78600 ".

As a basis to get approximate area of section, an average unit stress of 10,000 lbs. per sq. in. would require 11 or 12 square inches of metal. The width of member will be taken a 14 inches in order to give sufficient clearance for packing at upper chord joints. As the thinnest allowable metal is ¼ inch, the area of the cover will be 3.5 sq. ins., leaving the area of the two channels about 8 sq. ins.

The section will then be composed of two channels placed back to back, with a cover plate on top, and lacing bars beneath. A cover plate reduces the percentage of details and serves as a protection from rain.

The section taken is:



	Area
2 [s - 10" 15#:	8.92 sq. in.
1 Pl. 14" x ¼":	3.50 "
Total area	12.42 "

Distance of neutral axis above A A.

$$= \frac{8.92 \times 5.0 + 3.50 \times 10.12}{12.42} = 6.45''$$

Eccentricity of section $= 6.45'' - 5'' = 1.45''$

Moment of Inertia.. The moment of inertia of section equals

$I_{[} + A_{[} \, \varepsilon^2 + I_{Pl} + A_{pl} \, \overline{3.8}^2 = I$

$= 133.8 + 18.7 + 0.0 + 50.5 = 203.$

$r = \sqrt{\frac{I}{A}} = \sqrt{\frac{203}{12.42}} = \sqrt{16.36} = 4.04''$

Length of member $= 243''$

$\frac{l}{r} = \frac{243}{4.04} = 60.$

Allowed stress.

Dead load: $24000 - 110\frac{l}{r} = 17400$ lbs.

Live load: $12000 - 55\frac{l}{r} = 8700$ "

Required area:

Dead load:	$\frac{39,300}{17400}$ =	2.26 sq. ins.
Live load	$\frac{78600}{8700}$ =	9.04 " "
	Total	11.30 " "

Eccentric stresses. The position of the center of the pin should be such that the moments due to eccentric loading and that due to the weight of member will be approximately equal. To do this the center of the pin will be placed $1\frac{1}{4}$ inches above the center of the channels and will be .20 inches below the neutral axis. Then moment due to "ε" will be

$117,700 \times .20 = 23,600$ inch pounds.

From the formula on page 137 of Johnsons Modern Framed Structures;

$$f_1 = \frac{23600 \times 6.45''}{203 - \frac{117900 \times 243^2}{24 \times 28,000,000}} = 865 \text{ lbs. per sq. in.}$$

compression on lower side of member.

Moment due to weight of member. Weight of member equals

2 ⌊s 10"	— 30.00	lbs. per ft.
Pl. 14 × ¼	11.90	" "
20% for details	8.0	" "
Total =	49.9	" "

, which will be taken as 50 lbs. per ft.

Total weight = 50 × 20 = 1000 pounds.

Moment = $\frac{1000 \times 243''}{8}$ = 30400 inch pounds.

and

$$f_1 = \frac{30400 \times 3.8}{203 - 24.9} = 685 \text{ pounds}$$

compression on upper side.

Both of the above stresses may be neglected as each is less than the 10% allowable for such stresses. Besides in this case, they will almost exactly neutralize each other.

Excess of metal = 12.42 − 11.30 = 1.12 sq. ins.

Efficiency = $\frac{12.42}{11.30}$ = 1.10.

The succeeding members were designed in the same way.

<u>U_3-U_4 and U_2-U_3</u> having the same stresses were given the same section.
Required area = 12.85 sq. ins.
Section. 2 [s-10"-15#. Area = 8.92 sq. ins.
One plate 14" x 5/16". = 4.37 " "
Total area = 13.29 " "

<u>U_4 U_5</u> Center of upper chord
Required area 12.67 sq. in.
Section. 2 [s 10", 15# = 8.92 " "
One plate 14" x 5/16 = 4.37 " "
Total area = 13.29 " "

The end post will be designed under the portal system. (see page 21)

<u>Lower chord members.</u> allowed stress,
Dead load = 25000 lbs. per sq. in.
Live load = 12500 " " " ".

<u>L_0-L_1 and L_1 L_2.</u> Stresses as follows:
Dead load = 25600#
Live load = 51200#
Required area 5.12 sq. in.
Take two bars 3" x 7/8". Area = 5.25 sq. in.

$L_2 L_3$. Required area = 7.80 sq. in.
Section. 2 bars 4"×1" = 8.00 " ".

$L_3 L_4$ and $L_4 L_5$. Required area 8.83 sq. ins.
Take two bars 4"×$1\frac{1}{8}$" = 9.00 sq. in.

Web members. Hip vertical $U_1 L_1$
Required area 1.28 sq. ins.
Take 2 rods $\frac{7}{8}$" square = 1.52 sq. in.

Main tie $U_1 L_2$. Required area 4.15 sq. in.
Take 2 bars 3"×$\frac{3}{4}$". Area = 4.50 sq. in.

Main tie. $U_2 L_3$. Required area = 2.32 sq. in.
Take 2 bars 3"×$\frac{7}{16}$". Area = 2.62 sq. ins.

Counters. $U_3 L_4$. Required area = 1.22 sq. in.
Take 2 rods $\frac{7}{8}$" square. Area = 1.52 " ".

Counter. $U_4 L_5$. Required area 1.38 sq. in.
Take 2 rods $\frac{7}{8}$" square. Area = 1.52 " ".

Counter. $U_4 L_3$. Required area = 1.42 sq. in.
Take 2 rods $\frac{7}{8}$" square. Area = 1.52 " ".

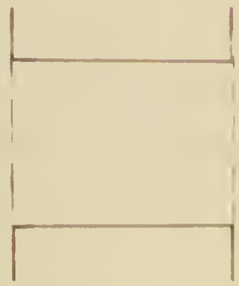
$U_3 - L_2$. Required area = 0.10 sq. ins.
Area of least allowable section $\frac{3}{4}$ sq. in.
Take one rod $\frac{7}{8}$" square. area = .76 sq. in.

Intermediate post. $U_2 L_2$.

Allowed stress:

Dead load $20000 - 90\frac{l}{r}$

Live load $10000 - 45\frac{l}{r}$.



Actual stress:

Dead load = 6900 lbs.

Live load = 21800 ″.

$\frac{l}{r}$ must not exceed 125.*

l = 23 feet = 276 inches

Take 2 channels 7″-$9\frac{3}{4}$#. area = 5.7 sq. in.

$r = 2.72$″. $\frac{l}{r} = \frac{276}{2.72} = 101$.

Allowable dead load stress 11000 lbs. per sq. in.

Allowable live load stress = 5500 lbs. ″ ″.

Required area 4.60 sq. ins.

Area of section 5.70 sq. in.

Post $U_3 L_3$. As $\frac{l}{r}$ must not exceed 125, no section 26 feet long can be less than 2-7″ channels. So section taken is 2 [7″ $9\frac{3}{4}$#.

l = 26 feet = 312 inches. $r = 2.72$″

$\frac{l}{r} = \frac{312}{2.72} = 115$.

Allowed dead load stress = 9600

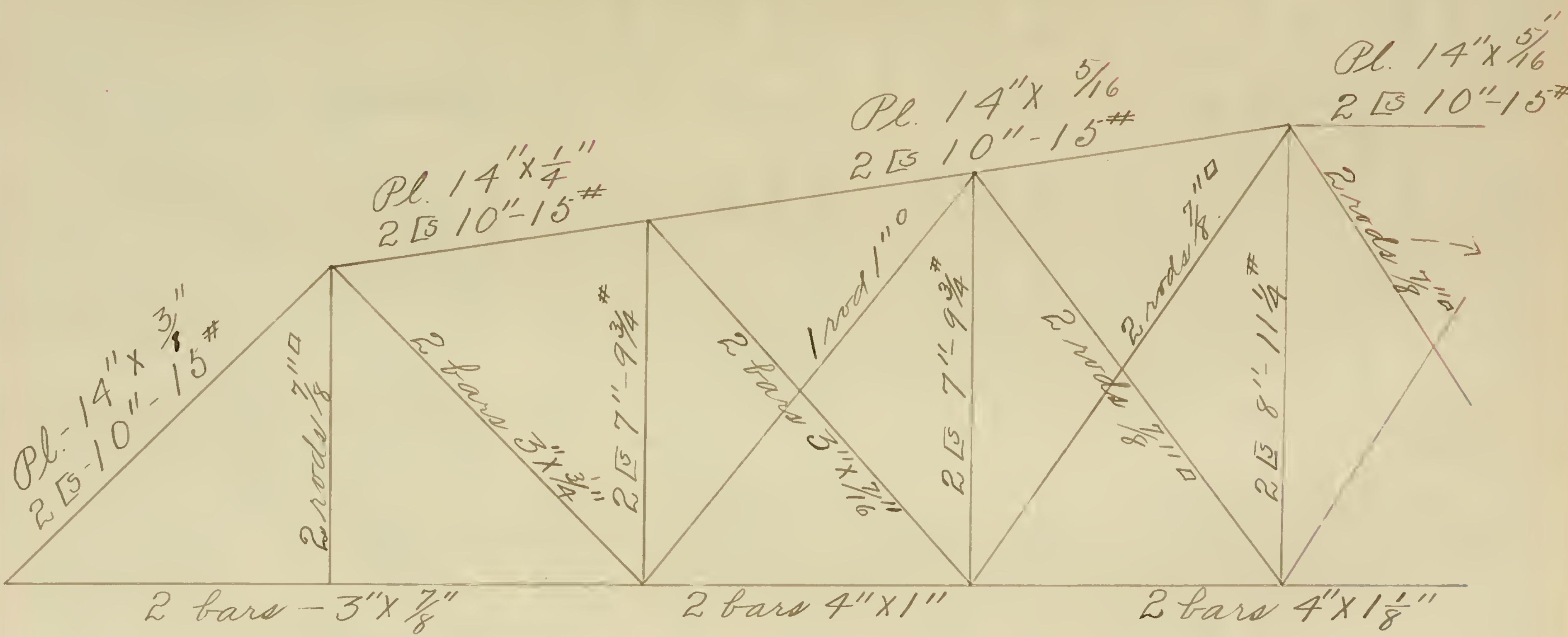
Allowed live load stress = 4800

* Specifications allow only 100, but 125 is allowable for highway bridges.

Required area 2.83 sq in.
Area of section 5.70 " ". Excess of area will be used to carry wind stresses down to lower lateral system and thus lighten wind force acting on end post.

Post U_4L_4. Stresses in member:
Dead load −6400 lbs.
Live load −12800 ".
Live load +8500 ".
Maximum compression +2100 lbs.
Maximum tension −19200 ".
Both stresses must be increased by .8 of lesser stress. This addition equals 2100 × .8 = 1680 lbs. and section must be designed for that stress requiring largest cross-section. As l/r must not exceed 125, it will be necessary to use 8" channels, whose value of "r" is 3.11
"l" = 348 inches. $\frac{l}{r} = \frac{348}{3.11} = 115$.
Required area for compression .79 sq. in.
Required area for tension 2.08 " ".
As the least allowable section is 2 [s 8"–11¼#, whose area = 6.70 sq. in. the member has a large factor of safety.

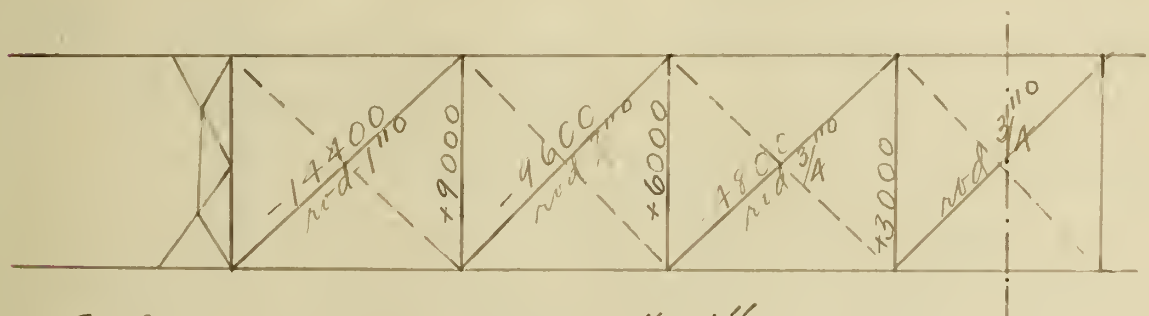
Sections.


Pl. 14"x 5/16"
2 [10"-15#
Pl. 14"x 5/16
2 [10"-15#
Pl. 14"x 1/4"
2 [10"-15#
Pl.-14"x 3/8"
2 [-10"-15#
2 rods 7/8"□
2 bars 3"x 3/4"
2 [7"-9 3/4#
2 bars 3"x 7/16"
1 rod 1"□
2 [7"-9 3/4#
2 rods 7/8"□
2 rods 7/8"□
2 [8"-11 1/4#
2 rods 7/8"□
2 bars - 3"x 7/8"
2 bars 4"x 1"
2 bars 4"x 1 1/8"

<u>Wind Stresses</u>. The specifications require that the top lateral system shall be designed for a wind load of 150 pounds per lineal foot. For a 20 foot panel this makes a panel concentration of 3000 lbs.

Top lateral System. The top lateral system is simply a truss placed between the main trusses. But as the loads may act on either side of the truss diagonals are required in each panel. Stresses in the lateral systems are most easily computed by algebraic coefficients. Part of the wind load will go down the vertical posts to the lower system, but the system will be designed to take the entire wind load.

Stresses and sections shown below:



All struts - 4Ls - 3"x2"x$\frac{1}{4}$".

The specifications allow a stress of 18000 lbs. per sq. in. in the diagonals, for stresses due to wind strains.

Design of section. $U_1 U_2$. Diagonal.
Stress = 14400 lbs.
Required area = $\frac{14400}{18000}$ = .80 sq. in.
Take one rod 1" round. Area = .785 sq. in.

$U_2 U_3$. Stress = 9600 lbs.
Required area = .53 sq. in.
Take one rod $\frac{7}{8}$" round. Area = .60 sq. in.

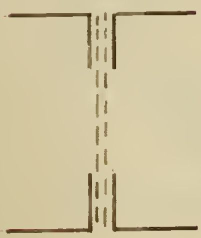
$U_3 U_4$. Stress = 4800 lbs.
Required area = .27 sq. in.
Take one rod $\frac{3}{4}$" round. Area = .44 sq. in.

$U_4 U_5$. This member has no stress according to calculations, but a rod $\frac{3}{4}$" round, area = .44 sq. in., will be used to stiffen truss and take any loads which might not be symmetrical.

Top lateral struts. The allowed stress in lateral struts is:

$13000 - 60\frac{l}{r}$, in which $\frac{l}{r}$ must not exceed 140. As the length of member is 192 inches, "r" must at least equal $\frac{192}{140}$ = 1.38". The section used is 4 angles, with unequal legs, joined in pairs by lacing bars, with the long legs placed out.

Below is a sketch of the section.

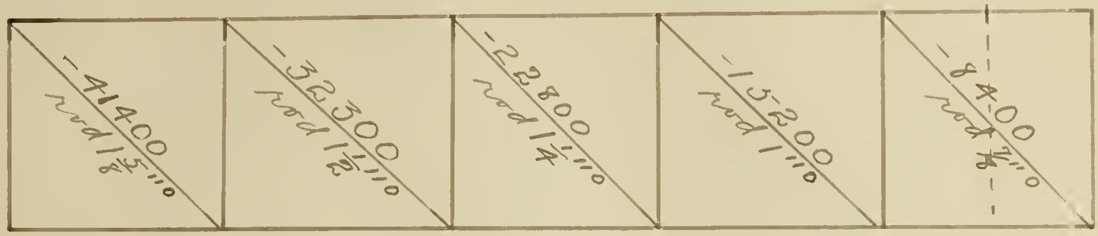


From Carnegie's Hand Book the smallest section with required value of "r" is 4 angles $3'' \times 2'' \times \frac{1}{4}''$, whose value of "r" is 1.56".

$l = 192''$. $\frac{l}{r} = \frac{192}{1.56} = 123$. Allowed stress is
$13000 - 60(123) = 4600$ lbs. per sq. in.
Area of 4 angles is 4.76 inches, so that section could a stress of
$4600 \times 4.76 = 21900$ lbs. As the maximum stress in any strut is 9000 lbs., above section has a large factor of safety.

Lower Lateral System. The lower lateral system may be said to consist only of rods as the floor beams act as struts. The specified loads are:
Dead wind load 150 lbs. per lin. ft.
Live wind load 150 " " ".
There will be added to this a dead load of 3000 lbs. which is assumed to come down the vertical posts and carried to the end of the bridge by the lower lateral system.

Stresses and sections shown below.



<u>Design of Sections</u>. Allowed stress in diagonal rods is 18000 lbs per sq. in.

Member	Req. area	Section	Actual area
L_0L_1	2.30 sq. in.	$1\frac{5}{8}''$	2.07 sq. in.
L_1L_2	1.78 " "	" $\frac{1}{2}''$	1.77 "
L_2L_3	1.27 " "	$1\frac{1}{4}''$	1.23 "
L_3L_4	.84 " "	$1''$	.78 "
L_4L_5	.52	$\frac{7}{8}''$	.60 "

<u>Portal system</u>

The duty of the portal bracing is to carry the wind stress to the shoe. Part of the wind load will go to lower lateral system by way of the intermediate posts. There will be overhead bracing or knee braces attached to each vertical post at a distance of 18 feet above the

centers of lower chord pins, as this allows sufficient head room. As these intermediate posts are fixed at both ends there will be a point of inflection 9 feet below the attachment of the over head bracing to the posts. The maximum moment in the post will therefore be equal to 108 P, where "P" equals the maximum force in pounds which the post in question can take to the lower lateral system. An investigation will now be made to find how much of the wind stress each post can take.

Post U_2L_2. This post is composed of two 7"-9¾# channels, placed back to back. The distance between centers of gravity of channels is 6.6 inches. Moment of inertia of section is:

I of channels	=	1.96
$A_{\square s}\left(\frac{6.6}{2}\right)^2$	=	62.30
Total	=	64.26.

Distance "c" to extreme fiber is 5 inches and $\frac{I}{c} = \frac{64.26}{5} = 12.8$.

As the direct longitudenal stress is small it will be sufficiently accurate to calculate stress by the formula $M = S\frac{I}{c}$.

Stress in post $= +28700$ lbs. (page 9

Actual area $= 5.7$ sq. in.

Actual stress $= \frac{28700}{5.7} = 5000$ lbs. per sq. in.

Allowable wind stress may be 25% in excess of dead and live load strains, so that, including wind strains the stress may be

$$6240 + 25\%(6240) = 7800 \text{ lbs. per sq. in.}$$

Amount which may be be caused by wind stress is $7800 - 5000 = 2800$ lbs. per sq. in.

From preceeding page, $M = 108P$; "M" also equals $S\frac{I}{c}$, so that we may write $108P = S\frac{I}{c}$, in which "P" is push on post in pounds and "S." is allowable wind load stress. We then get

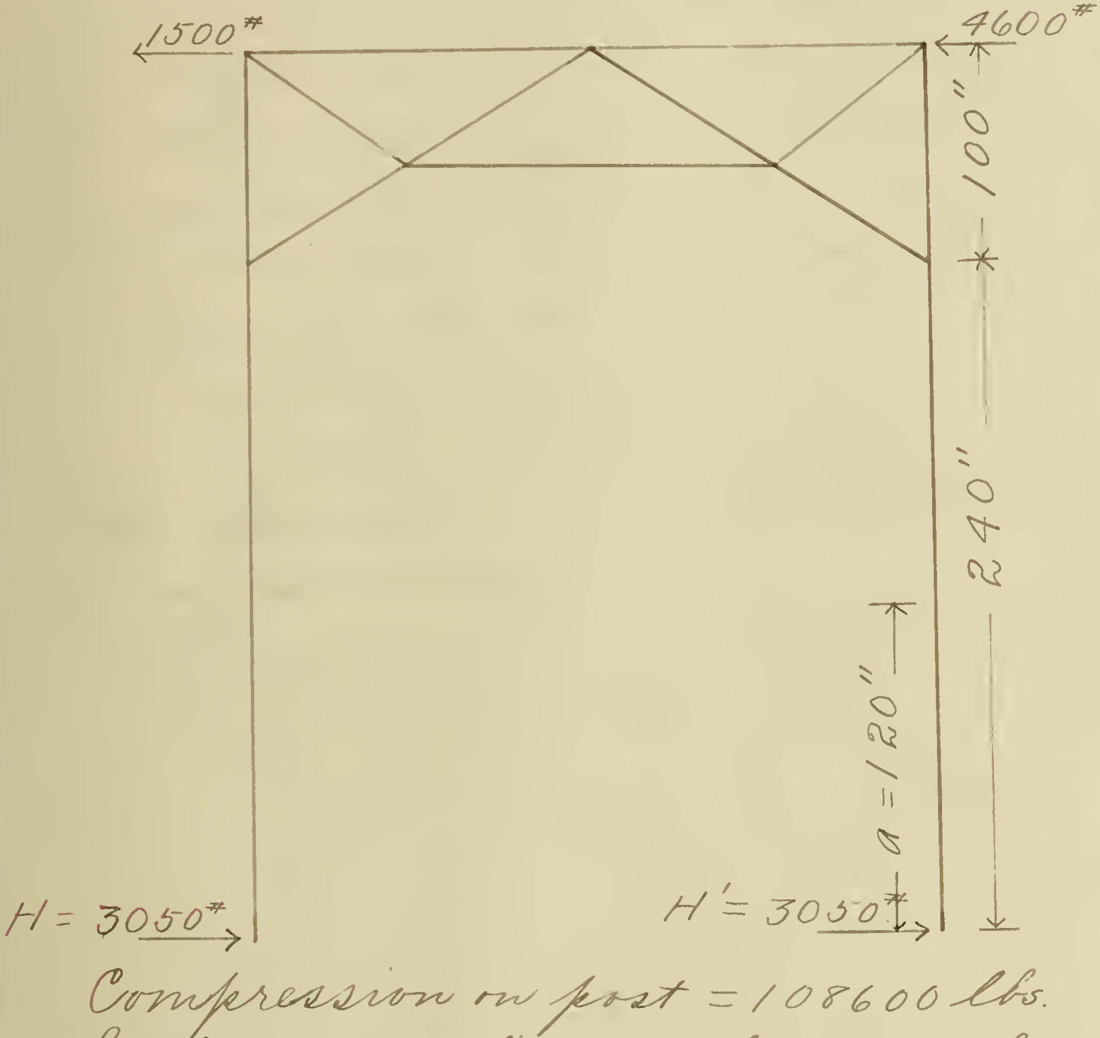
$$108P = 2800(12.8)$$
$$P = 330 \text{ lbs.}$$ There are 4 of these posts so that total load taken is 1320 lbs.

$\underline{U_3L_3}$. In same way the 4 posts U_3L_3 can take 2160 lbs. of wind load.

$\underline{U_4L_4}$ can take 5320 lbs.
Total possible load by all posts is $5320 + 2160 + 1320 = 8800$ lbs.

The total wind load is 21000 lbs. of which $\frac{21000-8800}{4} = 3050$ lbs. must be taken by each end post.

An investigation will be made to find if end post is fixed.



Compression on post = 108600 lbs.
Let "d" equal distance between bearings of shoe. H' = 3050 lbs. "a" = 120"
Now if $108600\frac{d}{2} > Ha$, then the end post is fixed. By equating the two

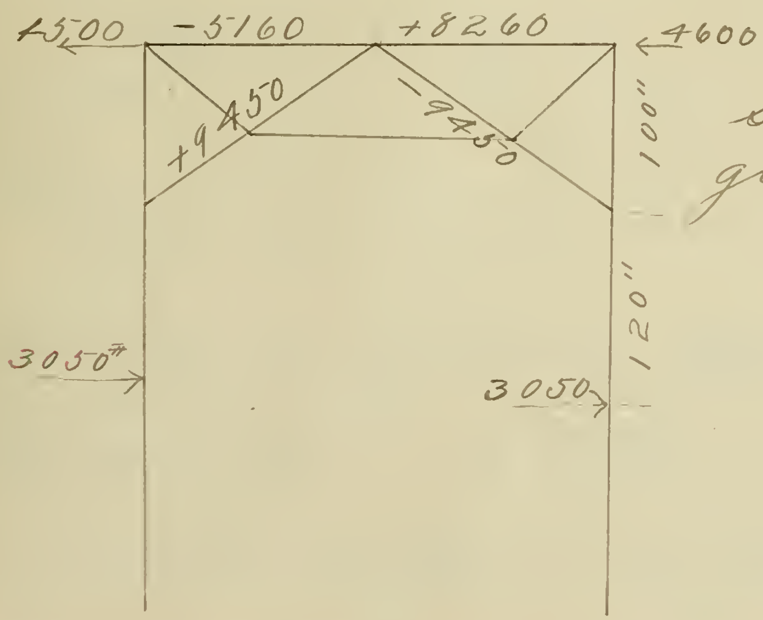
expressions and solving for "d", one may get a minimum value of "d" in order to fix the end post. Then

$108600\frac{d}{2} = Ha = 366000$ in. lbs.

$d = 6.8$ in. As the distance be-tween the channels of end post is 8.8 in. and the bearings of the shoe will be placed near this, it is seen that the post is fixed. As the post is fixed there will be a point of inflection midway between the shoe and the portal.

Design of Portal. The load "H" acting at the shoe may be assumed to act at the point of inflection, and the stresses are calculated under this assumption.

Stresses shown below:



Stresses are given in pounds.

Since the portal strut is braced at center by the diagonals which go to the end posts, only one pair of angles will be needed. Angles of same size as those of top lateral struts will be used, with the longer legs turned out.

Portal Strut U_1U_1. Unsupported length in vertial plane is 84 inches. In vertical plane, "l" equals 192 in. "r" equals .58 in. and 1.56 in.

$\frac{l}{r} = \frac{192}{1.56} = 138$. $\frac{l}{r} = \frac{84}{.58} = 145$. The larger value of $\frac{l}{r}$ will be used and allowable stress is:

$13000 - 60(145) = 4300$ lbs. per sq. in.

Actual stress $= +8260$ lbs.

Required area $= \frac{8260}{4300} = 1.92$ sq. ins.

Actual area $= 2$ Ls $- 3'' \times 2'' \times \frac{1}{4}'' = 2.38$ sq. in.

Member may be in tension. Stress $= 5160$ lbs. Required area is $\frac{5760}{18000} = .28$ sq. in. Actual net area is total area minus rivet holes $=$

$2.38 - .37 = 2.01$.

Diagonal Bracing: Stress $= +9450$ lbs.

Required area $= 1.65$ sq. in.

Actual area $= 2.38$ " ".

All portal sections are 2 Ls $3'' \times 2'' \times \frac{1}{4}''$

<u>Diagonal</u>. Stress = −9430 lbs.
Required area = 0.52 sq. ins.
Actual area = 2.01 " ".

Other parts of portal are simply braces to add rigidity and to brace main members. To keep the size of angles uniform throughout the portal, 4"×3"×$\frac{1}{4}$" angles will be used.

<u>End Post.</u>

Dead load stress = 36200 lbs.
Live load stress = 78400 ".
Maximum wind moment is 366000 inch pounds.

<u>Allowed Stresses:</u>
Dead load $20000-90\frac{l}{r}$.
Live load $10000-45\frac{l}{r}$.

Section:
2 [s - 10" - 25#. Area = 14.70 sq. in.
Pl 14"×$\frac{3}{8}$". Area = 5.25 " "
Total = 19.95 " ".

$l = 340''$. $r = 4''$ $\frac{l}{r} = \frac{340}{4} = 85$.
Allowed dead load stress = 12400
Allowed live load stress = 6200.
Required area = 14.60 sq. ins.

Stress due to wind moment:

$$f_1 = \frac{366000 \times 7''}{416 - \frac{108600 \times 340^2}{32 \times 28000000}} = 5230 \text{ lbs. per sq. in.}$$

Direct logitudenal stress equals

$$\frac{108600}{19.95} = 5400 \text{ lbs. per sq. in.}$$

and total stress is 10630 lbs. per sq. in.
Total allowable stress is:

$$\frac{108600}{14.60}(1.25) = 9200 \text{ lbs. per sq. in.}$$

The post is amply strong as 10630 pounds is not a dangerous stress, and such a stress could never occur on this bridge. A wind load of 75 lbs. per lin. ft., which is one half of specified load is as large as would ever occur in the heaviest Illinois wind storms.

Stresses in the pins.

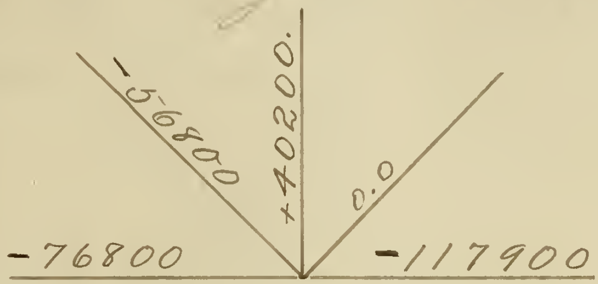
Bending Moment. The full computations for calculating the bending moment in the pin at L_2, the second panel point of the lower chord, will be given, as this is the most difficult pin to compute.

The pin will be investigated for two conditions:

(a) With all loads on bridge.

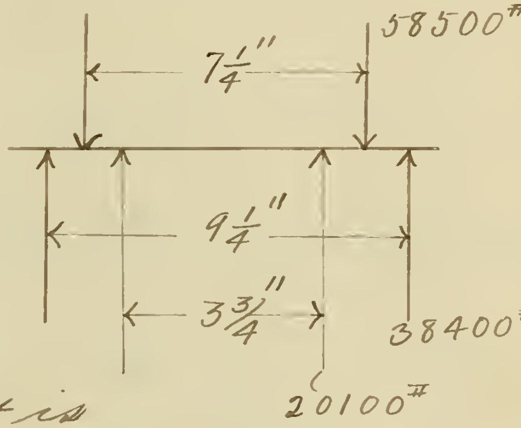
(b) With maximum stress in U_1L_2.

All loads on bridge. Stresses at L_2.



Pins are simply short beams with large concentrated loads, and are subject to all the laws of beams under various conditions of loading.

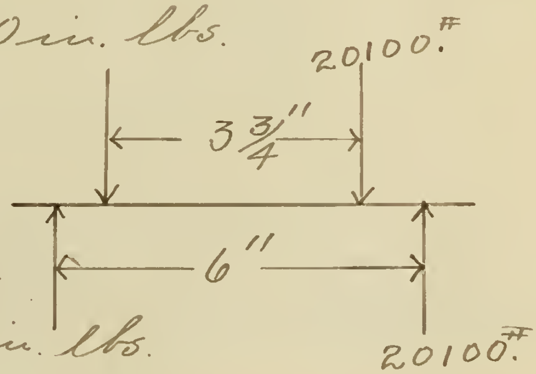
Horizontal forces:



Maximum moment is

$38400\left(\frac{9\frac{1}{4}-7\frac{1}{4}}{2}\right) = 38400$ in. lbs.

Vertical forces:

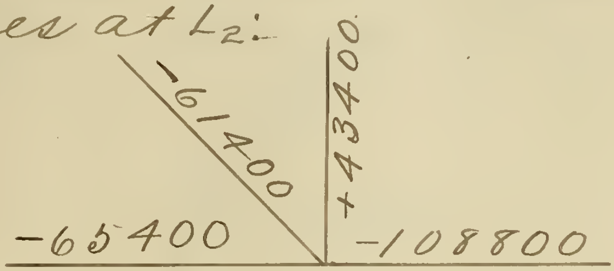


Maximum moment:

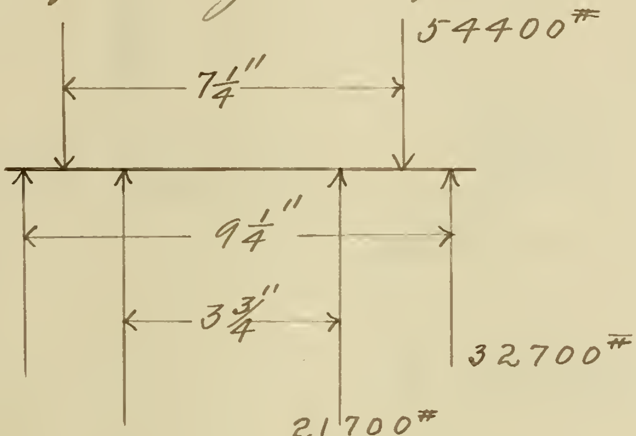
$20100\left(\frac{6-3\frac{3}{4}}{2}\right) = 22600$ in. lbs.

Total moment of all forces is
$\sqrt{38400^2 + 22600^2} = 44600$ in. lbs.

Bending moment in pin with maximum stress in U_1L_2.
Stresses at L_2:-

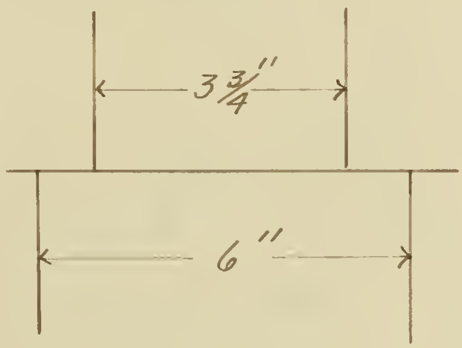


Moment of horizonal forces:



Maximum "M" $= 21700\left(\frac{7\frac{1}{4} - 3\frac{3}{4}}{2}\right) = 38000$ in. lbs.

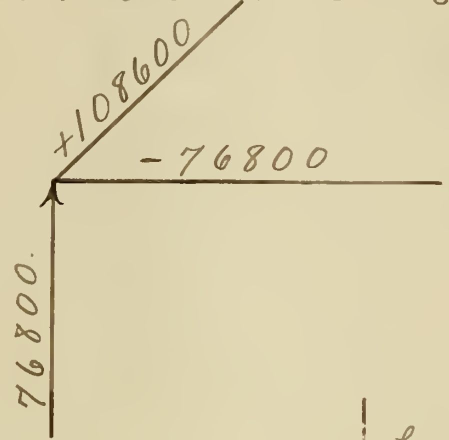
Vertical forces:



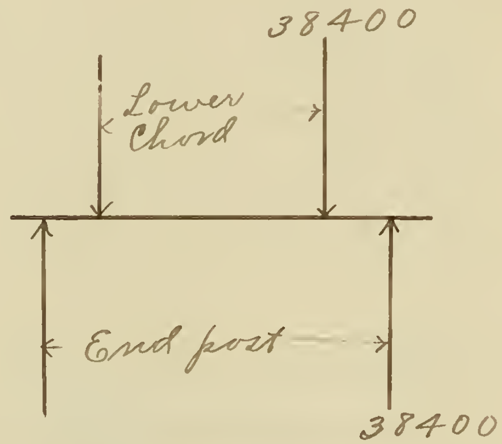
Moment $= 21700\left(\frac{6 - 3\frac{3}{4}}{2}\right) = 24400$ in lbs.
Total $= \sqrt{38000^2 + 24400^2} = 45100$ in. lbs., which is a maximum.

Shear on Pins.

The method employed in calculating shear on pins will be shown by making full computations for Pin L_0, at pedestal. There is only one condition for maximum; all loads on bridge. Stresses at L_0.

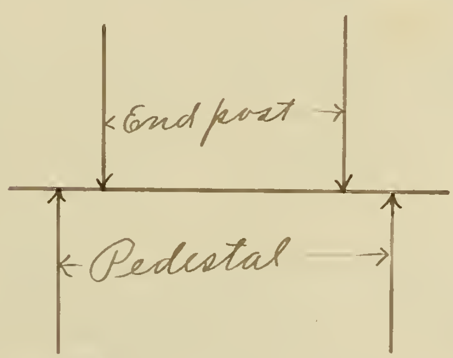


Horizontal shear:



Horizontal shear = 38400 lbs.

Vertical shear.



Vertical shear = 38400 lbs.

$$\text{Total} = \sqrt{\overline{38400}^2 + \overline{38400}^2} = 54300 \text{ lbs.}$$

In the way shown on preceeding pages the moments of all lower chord pins and the pin at portal were computed, and the shears on all pins were computed. Moments and shears shown in table.

Pin.	Moment	Shear.
L_0	57000 in. lbs.	54300 lbs.
L_1	38400 " ".	38400 ".
L_2	45100 " ".	38400 ".
L_3	65800 " ".	58500 ".
L_4	78600 " ".	66200 ".
U_1	62000 " ".	58900 ".
U_2	———	16800 ".
U_3	———	7600 ".
U_4	———	10850 ".

Pins at L_0, L_1, L_2, L_3, L_4 and U_1 are $3\frac{3}{8}$" in diameter. Allowed stresses:
Shear = 89400#. "M" = 75500 in lbs.

Pins at U_3, U_2 and U_4 are $2\frac{3}{4}$" in diameter.
Allowed shear = 64900. "M" = 47600

But two sizes of pins are used as it is not thought advisable to use too many sizes in the same bridge.

11 Grey/4

Floor Beams. Total load on floor beam will be taken as uniformly distributed. Distance between supports taken as 17 feet. Total load on beam is as follows:

Live load, $100 \times 16 \times 20 = 32000$ lbs.
Flooring, $10 \times 16 \times 20 = 3200$ " .
Stringers, 2800 "
Total load 38000 " .

$$\text{Moment} = \frac{38000 \times 204''}{8} = 969000 \text{ in. lbs.}$$

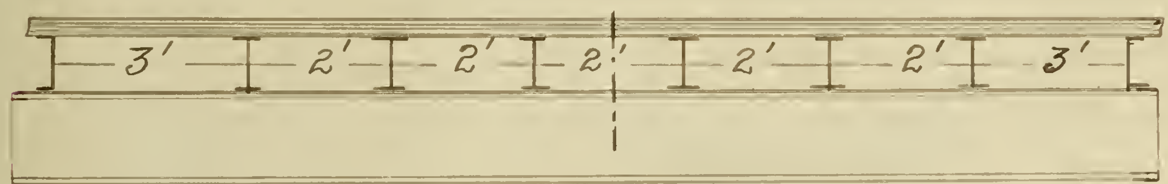
Allowable stress = 13000 lbs. per sq. in.

$$13000 \frac{I}{c} = 969000$$

$$\frac{I}{c} = 74.5$$

The best section in Cambria Hand Book is a 15"-60# I beam, whose value of $\frac{I}{c}$ is 81.2.

Spacing of stringers on the floor beams.

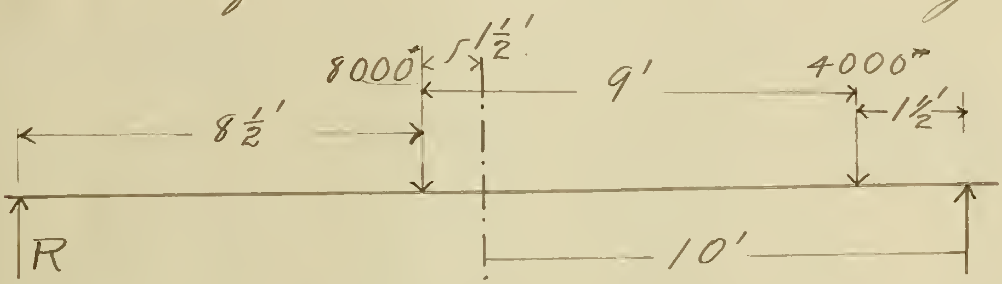


Channels are used as side stringers as heavy loads will not come near the sides of the bridge, and channels are better to bolt the nailing pieces to. The spacing is made 3 feet at end of beam.

<u>Stringers.</u> Panel length = 20 feet.
Flooring will be made of white oak $2\frac{1}{2}$ inches thick, and its weight will be 10 lbs. per sq. ft. Stringer is designed for two loadings:
(a) A live load of 100 lbs. per sq. ft.
(b) A 12000 pound traction engine.
Stringers will be spaced 2 feet apart.
Load on one stringer = 220 X 20 = 4400 lbs.

$$\text{Moment} = \frac{4400 \times 240}{8} = 132000 \text{ in. lbs.}$$

Moment of 12000 lb. traction engine:



$$\text{Reaction (R)} = \frac{4000 \times 2\frac{1}{2} + 8000 \times 11\frac{1}{2}}{20} = 5100 \text{ lbs.}$$

Moment = 5100" X 102" = 520 200 in. lbs.
This is assumed to be taken by four (4) stringers. Moment on each = 130050"#

$$\text{Moment of flooring} = \frac{20 \times 20 \times 240}{8} = 12000$$

Total moment = 142050 in. lbs.

<u>Section.</u> Allowed stress is 13000 in. lbs.

$$\frac{I}{c} = \frac{M}{S} = \frac{132000}{13000} = 10.15, \text{(for case a.)}$$

$$\frac{I}{c} = \frac{M}{S} = \frac{140050}{13000} = 10.9 \text{ (for case b.)}$$

A 7"-15# I beam is chosen. Its value of $\frac{I}{c}$ is 10.4.

Computation of Weight.

Name.	No.	Length	Cross Section	Wt. in lb. per ft.	Total Wt. Main.	Total Wt. Details
End Post.	4	Reference number L_0U_1.				
Channels	8	28.8	10"-25#	25#	5760	
Plates	4	28.8	14"x3/8"	17.85#	2056	
Pin pls.	16	1.25	9"x1/2"	15.3		306
Batten "	8	1.33	14"x1/4"	12.0		128
Lacing "	168	1.33	2 1/4"x3/8"	2.87		644
Rivet heads - 2096 at 9.95 per 100#						209
			Total weight =		7816	1287
Top chord U_1U_2.						
Channel	8	19.5	10"-15#	15.0#	2340.	
Plates	4	19.5	14"x1/4"	12.0#	936	
Pin pls.	8	1.25	9"x1/2	15.3#		153#
" "	16	1.00	8 x 1/4"	6.8		109#
Lacing "	120	1.33	2 1/4"x3/8"	2.87		460#
Batten	8	1.33	14"x1/4"	12.0#		128
1440 rivet heads		—				144
			Total weight -		3276	994
Top chord - 8 pieces. U_2U_3 - U_3U_4						
Channel	8	40.5	10"-15#	15#	4860	
Plates	4	40.5	14"x5/16"	14.9	2414.	
Pin pls.	24	1.33	9"x1/4	7.7		246
Spl. "	4	1.00	14"x1/4"	12.00		96
Batten "	16	1.33	14"x1/4"			256

Name	No.	Length	Cross Section	Wt. per ft.	Total Weight. Main.	Details
Lacing Pls.	240	1.33	$2\frac{1}{4}'' \times \frac{3}{8}''$	2.87		920
2760 rivet heads.						275
					7274	1793.
Top Chord. $U_4 U_5$ 2 Pieces						
Channels	4	20.1	$10''$ 15#	15#	1206	
Plates	2	20.1	$14'' \times \frac{5}{16}''$	14.9	599	
Pin Pls.	8	1.00	$8'' \times \frac{1}{4}''$	6.8		55
Spl. Pls.	4	1.50	$14'' \times \frac{1}{4}''$	12.0		72.
Batten Pls.	4	1.33	$14'' \times \frac{1}{4}''$	12.0		64
Lacing Pls.	60	1.33	$2\frac{1}{4}'' \times \frac{3}{8}''$	2.87		230
720 rivet heads.						72
					1805	493
			$U_2 U_3$ + $U_3 U_4$		7274	1793
			$U_1 U_2$		3276	994
			Total for top chord		12555	3280
Lower chord $L_0 L_1$ + $L_1 L_2$ 16 pieces						
Eye Bar.	16	20.0	$3'' \times \frac{7}{8}''$	8.93	2857	
		+2.2		"		314
$L_2 L_3$. 8 pieces			$4'' \times 1''$	13.6	2176	
Eye Bar.	8	20.0		"		372.
		+2.8	"			
$L_3 L_4$ + $L_4 L_5$						
Eye Bar.	12	20.0	$4'' \times 1\frac{1}{8}''$	15.3	3672	
		+2.4	"	"		440
			Total Bottom Chord		8705	1026.

Name	No.	Length	Cross Section	Wt. per ft.	Main	Details
Intermediate post U_2L_2.						
Channels	8	23.7	7″ – 9¾#	9¾#	1848	
Pin pls.	8	1.00	6″ x ¼″	5.1#		41.0#
Batten "	16	1.00	9½″ x ¼″	8.1		129#
Lacing	480	0.75	1¾″ x ¼″	1.50		540#
1248 rivet heads						124
			Total Wt.		1848	834
Intermediate post. U_3L_3.						
Channels	8	26.7	7″ – 9¾#	9.75	2078	
Pin pls.	8	1.00	6½″ x ¼″	5.53		44.0
Batten ".	16	1.16	9½″ x ¼″	8.1		129
Lacing ".	540	.75	1¾″ x ¼″	1.50		608
1368 rivet heads.						136
					2078	917
Intermediate post U_4L_4.						
Channels	8	30.0	8″ – 11¼#	11.25	2700	
Pin pls.	8	1.00	7″ x ¼″	5.95		48.0
Batten pls.	16	1.16	12″ x ¼″	10.20		189
Lacing	496	1.00	1¾″ x ¼″	1.50		744
1280 rivet heads						128
					2700	1109
		Total: intermed. posts.			6626	2860

Name.	No.	Length	Cross Section	Wt. per ft.	Main	Detail
Main Tie U_1L_2						
Eye Bar	8	28.28	3" x 3/4"	7.65	1731	
		+2.2	"	"	"	135
U_2L_3						
Eye Bar.	8	30.48	3" x 7/16"	4.46	1100	
		+2.2	"	"		78
U_3L_4						
Rod.	8	32.8'	7/8"□	2.60	669	
		+1.8	"	"		37
U_4L_5-U_4L_3						
Rod.	24	35.2	7/8"□	2.60	2196	
		+1.8	"	"		112.
U_3L_2						
Rod	4	32.8	1"□	2.62	344	
		+1.8				19
Hip Vertical.						
Rods	8	18.0	7/8"□	2.60	374	
		+1.8	"			19
Tension web members =					6414	400
Floor Beams.						
I beam	6	16.75	15"-60#	60#	6030	
I beam	2	17.25	15"-60#	60#	2070	
angles	32	1.10	3"x3"x3/8"	7.2		253
208 rivet heads.						20
					8100	273.

Name	No.	Length	Cross Section	Wt. per ft.	Main	Details
Stringers.						
I beam	54	21.0	7" - 15#	15#	17010	
Channel	18	21.0	7" - 9 3/4#	9 3/4#	3684	
					20694.	
Top Lateral Struts. 6 pieces						
Angles	24	16.0	3" x 2" x 1/4"	4.0	1736.	
Batten pls.	12	1.00	6" x 1/4"	5.1		62
Lacing	180	.75	1 1/4" x 1/4"	1.06		143
480 rivet heads.						48
					1736	253.
Top Lateral Rods. U_4U_5. U_3-U_4.						
Rod.	6	23.80	3/4"○	1.5	214	
		+2.0	"	"		18
U_2U_3.						
Rod.	4	23.80	7/8"○	2.04	198	
		+2.0		"		16
U_1U_2.						
Rod	4	23.80	1"○	2.67	234	
		+2.0	"	"		22
					646	56
Sway Bracing. U_3						
Angles.	8	16.0'	3" x 2" x 1/4"	4.00		512
"	8	.83'	3" x 3" x 1/4"	4.90		32
Rods	4	17.0'	3/4"○	1.91		130
Lacing	60	.75	1 1/4" x 1/4"	1.06		48
208 rivet heads.						20
						742.

Name.	No.	Length	Cross Section	Wt. per ft.	Main	Details
Sway Bracing. U_4.						
Angles	8	16.0	3"x 2"x ¼"	4.00		512
"	8	.83	3"x 3"x ¼"	4.90		32
Rods.	4	19.0'	¾" ⌀	1.91		144
Lacing	60	.75	1¼"x ¼"	1.06		48
208 rivet heads.						20
						756
Bottom Lateral Rods.						
L_0L_1	4	23.8	1⅝" ⌀	7.05	671	
		+2				56
L_1L_2	4	23.8	1½" ⌀	6.00	571	
		+2.				48
L_2L_3	4	23.8	1¼" ⌀	4.17	397.	
		+2				33
L_3-L_4	4	23.8	1" ⌀	2.67	234	
		+2				22
L_4-L_5	4	23.8	⅞" ⌀	2.04	198	
		+2				16
Plates	16	1.5'	9"x ⅜"	11.4		274
256 rivet heads						25
					2071.	474
Portal. U_1U_1 2 pieces.						
Angles	4	16.0'	3"x 2"x ¼"	4.00	257	
"	8	9.5	"	"	304	
"	4	8.3	"	"	133	
"	8	4.5	"	"	144	
"	12	.83	"	"		40

Name.	No.	Length.	Cross Sect.	Wt. per ft.	Weight	Total
Plates.	2	1.5'	$11'' \times \frac{3}{8}''$	14.4		43
"	4	1.0'	$10'' \times \frac{3}{8}''$	12.7		51
"	4	1.50'	$13'' \times \frac{3}{8}''$	16.5		99
408 rivet heads						40
					838	273

Pedestal. Roller End 2 pieces.

Plate.	2	2.0	$18'' \times \frac{5}{8}''$	38.2	153.
"	4	2.0	$9'' \times \frac{1}{2}''$	15.3	122
"	4	2.25	$2'' \times \frac{1}{2}''$	3.4	31
Angles.	4	2.00	$6'' \times 4'' \times \frac{1}{2}''$	16.2	130
Rods	4	1.50	$\frac{1}{2}''$ ⌀	0.67	4
Rollers	12	1.33	$3\frac{1}{2}''$ ⌀	32.7#	523
208 rivet heads.					21
				Total	984

Pedestal: At fixed is the same excepting rollers and roller details. Weight = 426.

4 Bearing plates $18'' \times \frac{3}{4}'' \times 2.0$ 367

Grand Total 1777

Pins and nuts.

Pins	10	1.25	$3\frac{3}{8}''$ ⌀	30.42	380
"	4	1.16	$3\frac{3}{8}''$ ⌀	30.42	142
"	6	1.25	$2\frac{3}{4}''$ ⌀	20.2.	151.
Nuts. 28 at 18.6#					480
12 at 13.7#					164
				Total	1317.

Bolts, nails, etc.- 500#

Lumber: $16 \times 180 \times 2\frac{1}{2} \times 4\frac{1}{4}$ 30500#

Summary of Weight.

Member. Name.	Weight. Main.	Details.	Total.
End Post.	7816	1287	9103
Top Chord.	12555	3280	15835
Lower Chord.	8705	1026	9731
Vertical Posts.	6626	2860	9486
Web. Tension	6414	400	6814
Floor Beams.	8100	273.	8373
Stringers	20694	000	20694
Top Lat. Struts.	1736	253	1989
Top Lat. Rods.	646	56	702
Sway Bracing	000	1498	1498
Bottom Lat. Rods.	2071	474	2545
Portal	838	273	1111
Pedestal.		1777	1777
Pins and Nuts		1317.	1317
Bolts.-Nails, etc.		500	500
Total metal.	76201	15274	91475

Lumber. $16 \times 180 \times 2\frac{1}{2} \times 4\frac{1}{4}$ = 30500

Total Weight. = 121975 pounds.

Estimated Cost of Bridge.

In estimating the cost the percentage of each shape of metal is multiplied by the cost of that shape, and the result taken as a percentage of the whole cost of metal.

Shape.	Weight.	% of Total.	Average Cost.	% of Cost.
Plates	14488	15.9	1.65	.262
Angles.	4165	4.6	1.60	.073
I Beams	25110	27.6	1.60	.441
Channels.	24476	26.9	1.60	.430
Pins & Nuts.	1317	1.5	4.00	.060
Bars & Rods.	20066	22.0	1.60	.352.
Rivets.	1353	1.5	2.10	.031
	90975	100%		1.649

Total cost of metal = 90,975 pounds of iron and steel at an average cost of 1.649¢ = 90,975 × 1.649¢ = $1500.17.

Shop work on metal: (Excluding stringers) at one cent per pound is 70281# @ .01 = $702.81

Add for freight to [illegible] @ $0.20 per 100# = 909.75 × .20 = $181.95

Cost of lumber at $20.00 per 1000 ft. B.M. 7200 ft. @ $20 = $144.00

Bolts, nails — $20.00

Haul. The length of haul is 3 miles and the price is $.30 per ton mile. Total weight = 121970 lbs = 61 tons at $0.30 per ton mile for 3 miles = 61 X 3 X .30 = $54.90

Erection at $1.25 per foot — $2,225.00

Painting. Two coats in field on 45.5 tons of metal. Paint at $0.75 per gallon.

60 gallons at .75 =	45.00
Labor. 20 days at $2.00	40.00
Total	$85.00

Bidding expenses	50.00
Traveling expenses to erect	75.00

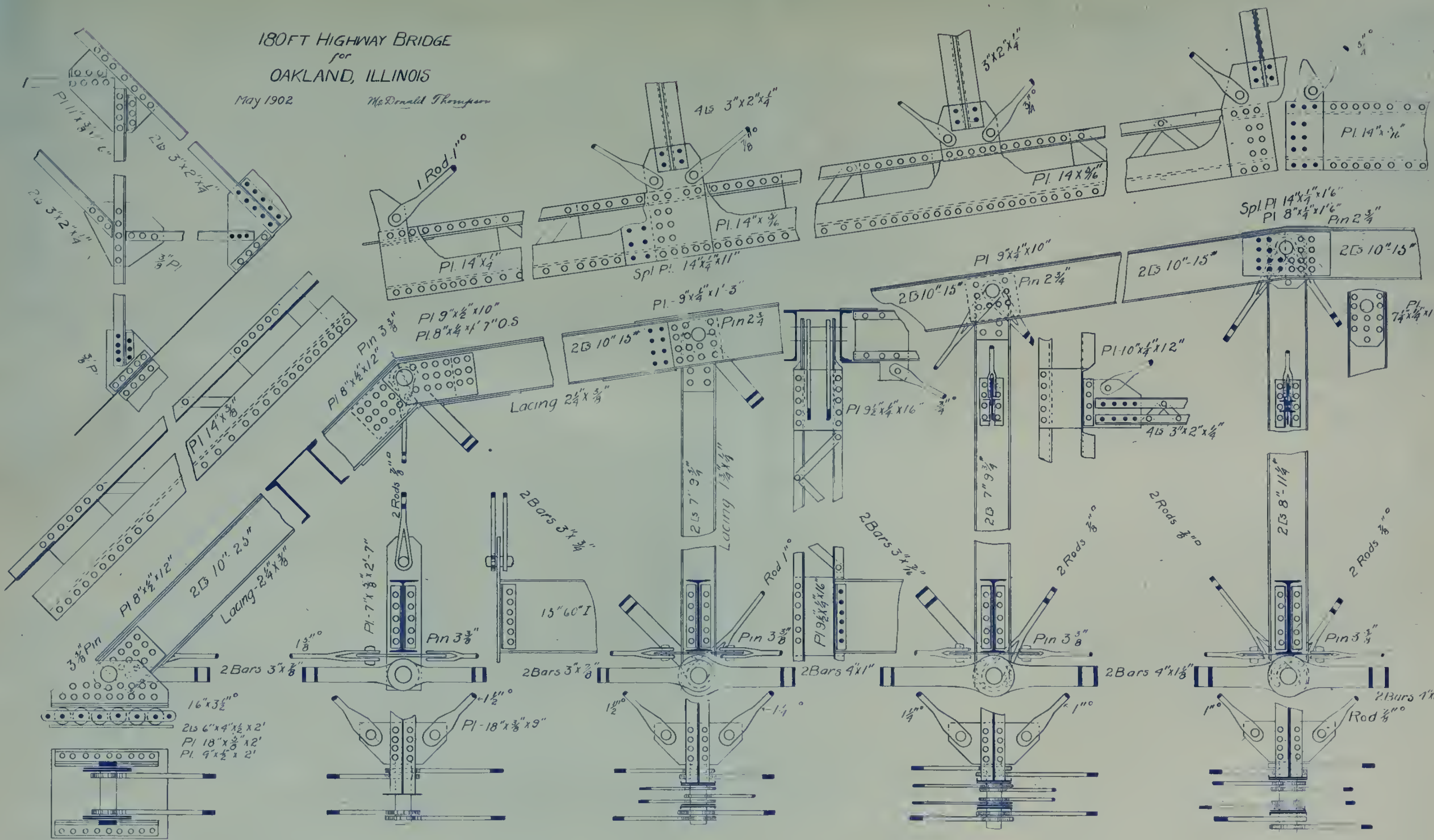
Summary of Cost.

First cost of steel in trusses. -	$1500.17
Shop work	703.81
Freight. -	181.95
Lumber	144.00
Bolts, nails, -	15.00
Haul to bridge site	54.90
Erection	2225.00
Painting	85.00
Bidding and traveling expenses	125.00
Total actual cost.	5033.93

In designing the portal sway bracing and lateral systems the members and connections were designed for rigidity as well as strength, in order that there might be no swaying or rocking motion under eccentric loads or from horses trotting over the bridge. It should not be necessary to place signs on bridges to caution drivers against fast driving, as any bridge worthy of the name will be safe against injury from any such causes.

The drawing shows general details of all members and connections. Five-eigths inch rivets are used throughout. The intention in working out the details was to make the joints uniformly stronger than the main members. Especial care was taken to do this in the connections of the floor system and in the end post as these are usually the least effective parts of the average highway bridge.

Plate I.


180 FT HIGHWAY BRIDGE
for
OAKLAND, ILLINOIS
May 1902
McDonald Thompson
1 Rod 1"○
4 ∟s 3"x2"x¼"
3"x2"x¼"
Pl. 14"x⅜"
Pl. 14"x¼"
Pl. 14"x 5/16"
Spl Pl. 14"x¼"x11"
Spl. Pl 14"x¼"x1'6"
Pl 8"x¼"x1'6"
Pin 2¾"
2 ∟ 10"-15#
Pl 9"x¼"x10"
Pl. 9"x¼"x1'3"
Pin 2¾
Pin 3⅜"
Pl 9"x½"x10"
Pl. 8"x¼"x1' 7" O.S.
Pl 8"x½"x12"
Lacing 2¼"x⅜"
Pl 14"x⅜"
2 ∟ 10" 25#
Lacing 2¼"x⅜"
Pl. 8"x½"x12"
3⅜" Pin
2 ∟ 3"x2"x¼"
Pl 11"x⅜"x1' 6"
⅜" Pl
2 Rods ⅞"○
2 Bars 3"x¾"
15" 60# I
Pl - 7"x⅜"x2'-7"
Pin 3⅜"
1⅜"○
1½"○
2 Bars 3"x⅞"
Pl - 18"x⅜"x9"
16"x3½"○
2 ∟s 6"x4"x½"x2'
Pl 18"x⅜"x2'
Pl. 9"x½"x2'
2 ∟s 7" 9¾#
Lacing 1¾"x¼"
Rod 1"○
Pin 3⅜"
2 Bars 3"x⅞"
1¼"○
Pl 9½"x¼"x16"
2 Bars 4"x1"
2 Bars 3"x 7/16"
2 ∟ 7" 9¾#
2 Rods ⅞"○
Pin 3⅜"
2 Bars 4"x1⅛"
1"○
Pl - 10"x¼"x12"
4 ∟s 3"x2"x¼"
2 Rods ⅞"○
2 ∟ 8" 11¼#
Pin 3⅜"
2 Bars 4"x1"
Rod ⅞"○
Pl 7¼"x¼"x12'